# LOW-LEVEL CONVERGENCE AND THUNDERSTORMS IN ALASKA

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## ABSTRACT

The association of thunderstorm occurrence in Alaska with low-level convergence is studied. The results indicate that the main contributing factor to thunderstorm development is the low-level convergence produced by the trough or Low pressure center that persists over Alaska during much of the summer.

## 1. INTRODUCTION

A number of studies have indicated that thermal instability is a necessary but not a sufficient condition for the development of thunderstorms. Byers and Rodebush [1] have concluded from these studies that some low-level convergence mechanism is necessary for the release of the thermal instability and the consequent development of thunderstorms. On the daily weather maps the most obvious mechanism that produces low-level convergence over Alaska during the summer months is a low-level trough or low pressure area. In the mean a thermal trough extends westward out of Canada through the central interior to the vicinity of the junction of the Yukon and Tanana Rivers (see fig. 1) and appears on the daily maps throughout a good portion of the summer. Other extensions and more temporary positions include: (1) the western portion extending southwestward through the Kuskokwim and Lower Yukon drainages, (2) the western portion extending westward over the Koyukuk and Kobuk drainages, and (3) the western portion of the trough cutting off and becoming a closed Low which may be located anywhere over the interior. At times this low-level thermal trough is modified or overshadowed by dynamic effects of the upper flow. Weak troughs in the upper flow may invade Alaska shifting the position of the thermal trough or intensifying it, and strong circulations usually eliminate it entirely.

## 2. THUNDERSTORM-TROUGH RELATIONSHIP

A study was made of thunderstorm occurrences during the summer months 1959 through 1961 in order to relate them to the position of the trough. A total of 154 thunderstorms were reported during this period. Twenty-four of the occurrences were associated with fronts or troughs moving through the area with the upper flow. These troughs were accompanied by cloudiness and precipitation which resulted in little available solar heating. They were attributed directly to dynamic causes and were not included in the tabulated data given in tables 1 and 2.

The remaining 130 thunderstorms were grouped first with respect to the pressure difference between the location of the occurrence and the lowest pressure of the trough at the point nearest the occurrence; and second with respect to the distance in miles from the occurrence to the trough at the point nearest the occurrence. The results are shown in tables 1 and 2. In order to increase the number of cases it was decided to use lightning-caused fires as thunderstorm occurrences [2]. This may introduce


FIGURE 1.—Major river drainages of the interior of Alaska.

TABLE 1.—*Thunderstorm-lightning fire occurrence distribution with respect to pressure difference*

| Pressure difference (mb.) | Thunderstorms | | Lightning Fires | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| Less than 2 | 96 | 74 | 157 | 77 |
| 2 to 4 | 29 | 22 | 41 | 20 |
| 4 to 6 | 5 | 4 | 7 | 3 |

TABLE 2.—*Thunderstorm-lightning fire occurrence distribution with respect to distance*

| Distance (miles) | Thunderstorms | | Lightning Fires | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| Less than 50 | 68 | 52 | 123 | 60 |
| 50 to 100 | 30 | 23 | 43 | 21 |
| 100 to 150 | 19 | 15 | 31 | 15 |
| 150 to 200 | 8 | 6 | 8 | 4 |
| More than 200 | 5 | 4 | 0 | 0 |

errors into the data for two reasons: (1) the fire may have been caused by lightning on a previous day, and (2) it is not always possible to determine the exact cause of a fire. To partially offset (1) any fire discovered before 1000 LST was counted as having started from lightning the preceding day. In addition the large number of cases tends to average out the errors introduced. These occurrences have been grouped in the same manner as actual thunderstorms and are given in the columns on the right of tables 1 and 2. A comparison of the percentage of occurrences between the thunderstorms and lightning-caused fires in tables 1 and 2 would seem to justify the use of the above data.

It will be seen from table 1 that 74 percent of the thunderstorms occur within 2 mb. of the trough line and nearly all within 4 mb. Table 2 shows that more than half the storms occur within 50 mi. of the trough line and nearly all within 150 mi. The use of these limits allows us to reduce the forecast area under that obtained by using the stability index and heating alone. Under conditions of moderate to strong gradient the pressure difference will give the smallest area while under conditions of weak gradient the results of table 2 can be used.

The density of occurrence can also be visualized from these data with storms being more numerous along the trough line and gradually thinning out with distance. The storms appear to occur with equal frequency on either side of the trough.

## 3. STABILITY INDEX

The Showalter Index [3] gave a good representation of the instability present but failed too often in individual cases to be an effective guide. This stems from the fact that all but two of the radiosonde stations in Alaska are coastal stations. The air is frequently cooled in the lower layers by the cold water, resulting in a more stable lapse rate than that observed at inland stations. For this reason the Lifted Index [4] was used. The Lifted Index gave a smoother field when analyzed and more nearly represented the instability that was available during the time of maximum thunderstorm occurrence. All of the occurrences in the study were observed with a Lifted Index of +4 or less. It was also noted that the maximum thunderstorm activity seldom occurred in the area of maximum instability.

## 4. AN EXAMPLE

A series of surface charts for the period June 27 through June 30, 1959 are shown in figure 2. The charts were obtained from the operational analyses of the Forecast Center at Weather Bureau Airport Station Anchorage and reanalyzed for 2-mb. intervals of pressure. Lightning fire and thunderstorm occurrences are shown on each chart.

This series was selected to show the evolution and movement of the trough itself rather than its relation to thunderstorm occurrence. In figure 2a (0000 GMT, June 27, 1959) the trough occupies a position through the central interior and is well organized with a central pressure of 1007 mb. Figure 2c shows that the trough has moved steadily northward and weakened to 1017 mb. On the following map (fig. 2d) it is again located near its original position and has deepened to 1013 mb. Figure 3 shows the successive daily positions of the trough during this period.

## 5. CONCLUSION

Several points revealed by this study indicate that low-level convergence produced by the trough or Low that is often present over Alaska during the summer is the *main* contributing factor to thunderstorm development. They are:

1. The thunderstorms show a great affinity for this trough or Low.
2. The area of maximum heating does not always coincide with the area of development even when instability is present.
3. The area of maximum instability seldom coincides with the area of maximum development even when adequate heating is available.
4. Few thunderstorms developed when this feature was not present. This is particularly surprising when one considers that orographic lifting and high-level heating are nearly always present over some part of the interior during the summer.

The incompleteness of the observational data during the period covered by this study prohibits drawing definite conclusions on the occurrence of a trough without thunderstorms. Preliminary results of data collected during

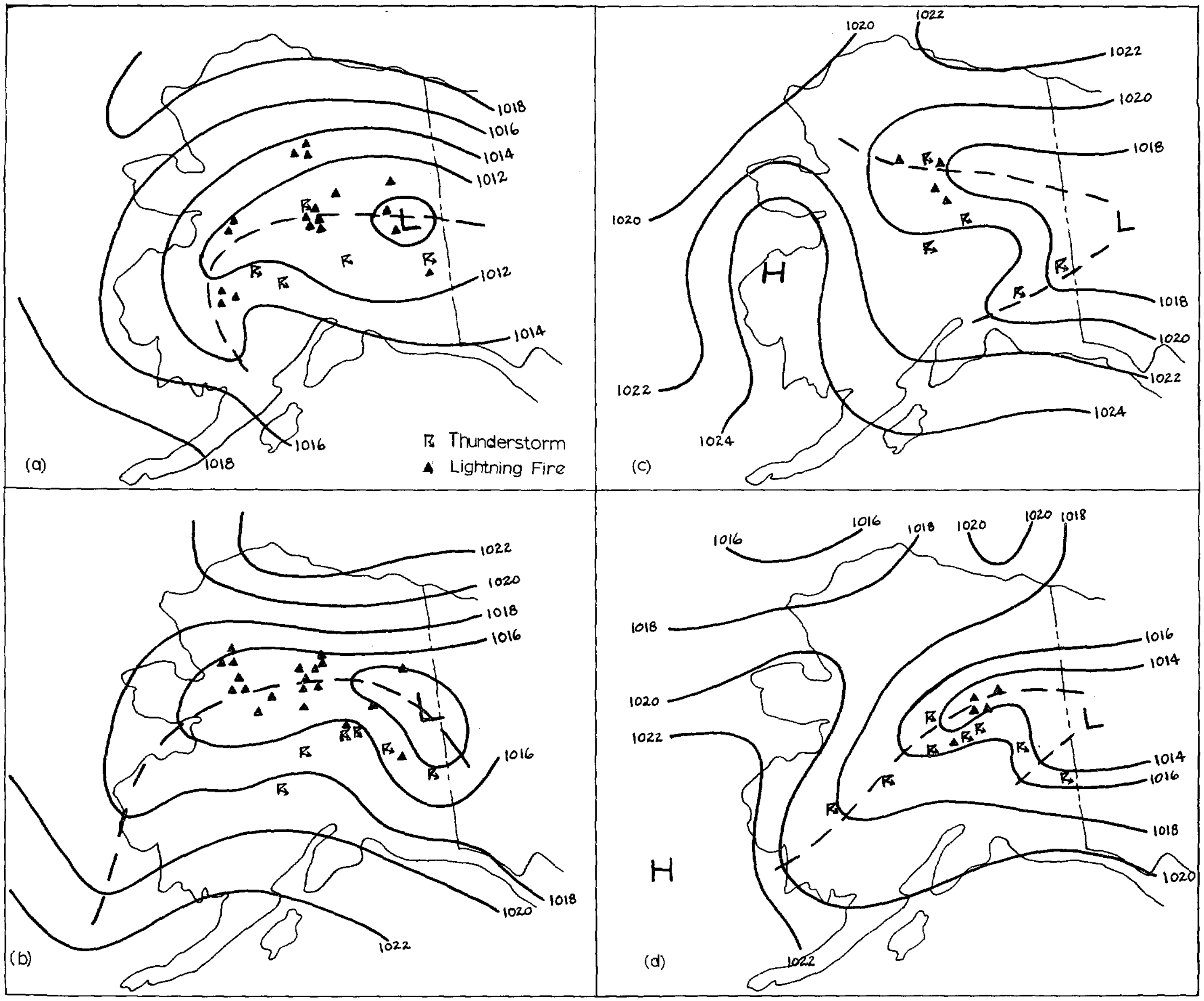


Figure 2.—Surface analysis (0000 gmt) with location of thunderstorms and lightning fire occurrences, (a) June 27, (b) June 28, (c) June 29, and (d) June 30, 1959.

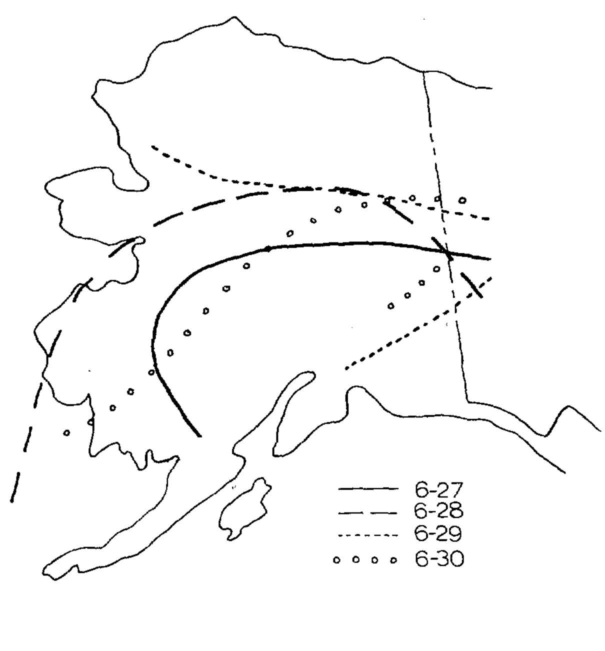


Figure 3.—Daily trough positions at 0000 gmt for the period June 27–30, 1959.

the summer of 1962 show that thunderstorms or cumulonimbus clouds were observed with 80 percent of the trough occurrences. Stability prohibited development on about 10 percent and the remaining 10 percent were indeterminate. During this study the opinion was formed in the author's mind that except for cases of well-developed large-scale subsidence, adequate moisture is nearly always available for convective activity over Alaska. If this is true the release of instability by low-level convergence will produce thunderstorms in a very high percentage of the trough occurrences.

## REFERENCES

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